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REVIEW ON HERBICIDES, WEED CONTROL PRACTICES AND MANAGEMENT

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ABSTRACT

A multifaceted approach is required for weed management, made upon basic understanding of weeds and the crop. Weed management may encompass both chemical methods, nonchemical methods (herbicides), or a blend of the two. Chemical weed measures include use of herbicides which provide a means to suppress or even eliminate standing weeds. Cultural measures include physical and ecological management practices that can be employed to eliminate the need for herbicide control. Mechanical control comprises of various methods like mowing, pulling, disking and digging. Biological control employs the use of various living agents to suppress vigor and spread of weeds. Although the best practice include integrated weed management.

KEYWORDS: Weeds, Chemical, Cultural, Mechanical, Biological Control

INTRODUCTION

Conventionally, a weed is distinctly defined as any plant growing where it is not required. This definition can relate to crops, native plants as well as non-native species. If it is measured to be a nuisance where it is increasing, it can be termed a weed. However, weeds are not just unnecessary species; they can have substantial negative and rarely positive impacts when they are there. Weeds can efficiently can lesser yields, compete with crop species and may increase labor requirements and, eventually increase food costs for the consumer (Klingman and Ashton, 1975). A plant is often termed a "weed" when it has one or more of the following characteristics like little or no value (as in medicinal, material, nutritional or energy), Rapid growth and/or ease of germination and Competitive with crops for space, light, water and nutrients.

WEED CONTROL METHODS

Weed control is the botanical component of pest control, which attempts to stop weeds from challenging with domesticated plants and livestock. Several strategies have been developed in order to contain these plants (Ambach, *et al.*, 1982). Weed represent about 0.1% of the world flora and in agro-ecosystems, weeds and crops have co-evolved together right from the prehistoric times as revealed by pollen analysis studies.

Beginning from Prehistoric era, humans saw the necessity to deal with weeds. Closely 3000 years ago, people in Europe cleaned and removed trees and bushes from around nut and oak trees to increase the number and of acorns and nuts (Bocquet, 1979). All through history, numerous methods of control have been developed, all of which are still used today. Though integrated weed management practices were developed and practiced which will ultimately offer effective weed control through chemical as well as mechanical, biological and cultural methods. Because an understanding of the other methods can be helpful in developing comprehensive weed management strategies, they are briefly described in the following paragraphs.

Chemical Weed Control

In the early 1940's the discovery and introduction of the phenoxyacetic herbicides laid a novel era in the field of agricultural weed control. Prior to the introduction and development of the organic herbicides, like 2, 4-D, chemical weed control completely and majorly relied on huge quantities of inorganic compounds that had potential hazards to non- plant organisms. (Amor and Richardson, 1980). Till the time that alternative weed control tactics will be available as viable and effective options in addition to chemical weed control, the herbicide control as a primary weed control practice will be needed in order to withstand global food necessities and sustain productive, effective and lucrative agricultural systems (Buhler, 2002).

Herbicide application can provide the most effective and time-efficient method of managing weeds. Many herbicides are available that provide effective weed control and are selective in that grasses are not injured. Along with herbicide use is user liability and compliance with all product label requirements for herbicide handling, use, and cleanup (Norris, 2007). Compared to mechanical weed control methods, herbicides provide greater efficacy at lower cost. Herbicides are properly managed; provide relatively long term weed control. Spraying equipment is generally lesser in cost and easier to operate than the heavy equipment used in various methods of mechanical weed control. In context to Chemical weed control which is more rapid one could say that it provides longer time weed suppression than many mechanical methods. Besides, results of herbicidal weed control shows greater grass production in pastures as compared to clipping of weeds (Baumann, *et al.*, 1991). Chemical methods provide greater flexibility and lessen labor costs, makes management of labor easy and most notably, decrease the risk of mishaps by plummeting exhaustion and worker's exposure to sharp implements and power equipment. There are several examples of the common chemical weed control practices in a variety of cropping systems: conventional tillage, conservation-agricultural systems, conventional weed management and herbicide-tolerant management cropping patterns. Lack of effective herbicides could be one major reason for demoralizing the world food markets.

Conventional-Tillage Systems

Historically, row crop systems have been introduced and planted into cultivated areas for a various of motives including: enlarged incorporation of precipitation, augmented aeration of soil and to interrupt the surface crust (Akemo, *et al.*, 2000). In more current decades, tillage has been lauded as an efficient means of weed control for small seeded annuals. Tillage of farming areas leads to the burial of weed seed and reduces their exposure to necessary stimuli for germination.

Conservation-Agriculture Systems

Broadly conservation tillage is the term pragmatic to these non-conventional tillage system practices. As conservation tillage refers to wide range of systems with different aims, a single definition is not completely agreed upon by the different scientific communities. However, a comprehensive and most accepted definition is -any tillage practice with minimum thirty percent plant residue on the soil surface after planting in an attempt to reduce and water soil loss (Upchurch, *et al.*, 1969).

Weed Management in Conventional Crop Varieties

Majority of conventional farming systems which are in use today incorporates some kind of chemical methods of weed control into their management strategy. With widely adopted and accessible herbicide tolerant crops, one can simply

forget the diverse challenges faced by those who still use old and conventional crop cultivars. Nevertheless, a big majority of the herbicide market is still geared to these conventional systems (Sankula, *et al.*, 2004).

Management in Herbicide-Tolerant Crop Varieties

In the late 1980s a novel design of chemical weed control was developed and introduced with the progress and development of genetically engineered and modified glyphosate-tolerant crops (Appleby, 2005). After that, numerous other non-selective herbicides, along with glufosinate and bromoxynil, have been used to create herbicide-tolerant cultivars in few of the major crops in United States. Until this time, conventional breeding techniques were able to accomplish this achievement to a partial level commercially with selected species and herbicides (Green, *et al.*, 2008). With the introduction of these crops in market in the 1990's, noteworthy adoption rates, around whole conversion in few instances, have redefined weed control and management strategies in soil- plant agricultural systems.

Usefulness of Chemical Methods (Herbicides)

Herbicide is the most powerful and effective single weapon towards weed control and management. It basis has the highest consumption, production and market share among all pesticides. Herbicides particularly pre-emergence ones control weeds right from the beginning of their germination and thus prove to be more efficient than many other methods of weed control. Most herbicides prove to be more economical than mechanical & manual methods particularly where manual laborer costs higher. They can substitute mechanical control of weeds in many situations and hence reduce mechanical damage (stalk breakage, lodging, up-rooting, root damage, etc) to crops. They control weeds where other methods is difficult to execute, e.g. in wet & marshy soils under humid conditions, within or between narrow-rows of crops.

Limitations of Chemical Methods/Herbicides

Herbicides may cause inadvertent/unintentional injury to crop and other non-target vegetation in an area by faulty application techniques (using inappropriate herbicide, its dose & spray volume, spraying in windy days, etc). Many herbicides are narrow-spectrum ones (i.e. the spectrum of weed kill is narrow). Chemical method may be less economic under small and fragmented holdings of the farmers. It poses high risk towards adoption in crops particularly by illiterate farmers. Proper technical know-how of the herbicide is the pre-requisite for its application to crop to ensure crop safety. Farmers are required to be trained for its correct use. Herbicides may pose toxicity to other non-target organisms such as soil micro-flora and micro-fauna, vertebrate animals and crops grown in succession. They may be the cause for concern and threat on their long and continued use to human health and safety.

Cultural Weed Control

In the United States though the bulk of farming systems use nearly all form of chemical weed control methods for thoroughgoing weed suppression, a minor part of the farming society has initiated to emphasize on ecological and physical management practices that can be engaged to decrease or eradicate the want for herbicide control. The fundamental basis for these management strategies is that with a thought of in what way and to what extent farming practices may touch weed populations. These cultural practices can be employed in such a technique that weed species can be skillfully controlled while at the same time economic loss can be reduced, conserving environmental suppleness (Westerman, *et al.*, 2005).

It has been noted that weed populations can be effected by variety of cultural practices which includes: crop rotation, tillage, planting time, cover cropping and row spacing. Time after time, when used in addition to herbicides three major of these cultural practices like crop rotation, tillage and cover crop residues have been shown to successfully maintain low levels of weed growth and populations. Application of these strategies gives numerous preventative measures counter to weed establishment just before planting; reduced emergence allows in-season weed control to be achieved through reduced herbicide applications or through other cultural control techniques (White, *et al.,* 2007).

While agricultural community tries to reduce its reliance on chemical weed management as its solitary weed control practice, it is anticipated that these methods will achieve bigger attention by researchers (Cromar, *et al.,* 1999). These strategies and techniques with improved study and understanding can be well adapted for execution into row crop systems to reduce the dependence on use of herbicide (Franke, *et al.,* 2009). Cultural control includes those management practices that modify the agro ecosystem to make the pasture, crop, or forest ecosystem resistant to weed establishment and, at the same time, support overall economic goals. Some Examples like for superior yields one can fertilize pastures along with faster and deeper ground cover; using intensive grazing management systems in which one can manage livestock(Smith, *et al.,* 1986), pastures are greatly grazed for small phases, permitting grazing to resuscitate the forage and crushing to subdue the weeds, trailed by a lengthier rest period for recover of grass; and integrating sheep or goats to browse brush species and fowl to graze herbs and grasses (Field and Popay, 1996).

Land and Crop Selection

You should aim to establish a vigorous crop that competes effectively with weeds. This approach starts with the land selection. Crop selection can reduce the effects of weed competition. One criterion in selecting a crop should be the weed problems of the field.

Crop Rotations

Crop rotation is considered as a “panacea” as for controlling several insect pests, diseases and weeds under crop field ecosystems so for maintaining soil health and sustained crop production. It is highly effective against parasitic weeds such as *Striga hermonthica/asiatica* (mainly in sorghum and maize), *Orobanche ramosa* (in *Brassicas* & solanaceous crops), *Orobanche cernua* (in tobacco), *Orobanche crenata* (in faba bean), *Cuscuta chinensis* (in alfalfa), *Cuscuta epilinum* (in linseed), *Cuscuta campestris* (in niger) (Parker, 1979; Parker and Riches, 1993) and crop-associated weeds like *Avena ludoviciana/fatua* and *Phalaris minor* (in wheat), *Cichorium intybus* and *Coronopus didymus* (in Egyptian clover/berseem), *Echinochloa colona/crusgalli* (in rice) (Gupta, 1998). For example, vegetable pea, potato, mustard/gobhi, sarson, Egyptian clover/berseem if adopted in sequence after rice during winter season, *Phalaris* problem could be reduced to a great extent in North-western wheat belt of India (Singh and Singh, 2006).

Adapted Crop Varieties

Once a crop is selected, use adaptive, vigorous varieties resistant to diseases. Disease-infested plants cannot effectively compete with weeds.

Proper Row Spacing and Plant Densities

Narrower row spacing and proper plant densities assure that the crop rapidly closes canopy. Later -emerging weeds could be shaded out by closed canopy shades and germination could also be prevented of weed seeds demanding

light. Weeds occasionally are problematic once canopy closing follows. Plant density and Proper row spacing also permit row cultivation (Rolston and Robertson, 1976).

Correct Planting Time

Alternative cultural method to increase crop competitiveness is to custom the right planting time. Most of crops can be separated into warm- and cool-season plants, which depend on the ideal optimal temperature for their development (Jansen, 1964). Early seedling vigor and the time of emergence of the crop, both of these two parameters are greatly affected by the planting date of the plant, which are very significant in determining crop competitiveness.

Adequate Fertilization, Insect and Disease Management

Suitable insect, adequate fertilization and disease control and management are imperative in reassuring a competitive crop. Satisfactory fertility promises rapid, even germination and worthy crop growth, which enhance the crop's competitive ability. While poor insect and disease control reduce a crop's competitiveness, insufficient weed controls can also grounds insect and disease complications (Mc Whorter, *et al.*, 1972).

Mulching

Weeds can be well managed by mulching. Mulches may be well categorized as either synthetic (plastic) or natural (leaves, straw, compost and paper). As natural mulches are very challenging to apply over big areas, they are finest for minor and specialized areas. To prevent light penetration natural mulches should be well spread uniformly at least 11⁄2 inches dense and thick over the soil (Marshall, *et al.*, 2003). Natural mulch materials should not have weed seeds and other pest organisms and be sufficiently heavy so that they are not simply banished by wind or water. A main advantage of natural mulches is that they add organic matter to the soil. Synthetic mulches control weeds within the row, conserve moisture, increase soil temperature, and are easy to apply.

Mulching may broadly be categorized into i) live mulch (cover crop, green manure crop and inter-crop etc) and ii) dead mulch. Dead mulch could be a) organic mulches such as i) residue mulch (dry residues of plants/crops, e.g. straw, groundnut shells, sawdust, grass clippings, bark from treads, etc.), ii) organic matter mulch, e.g. compost, FYM; b) synthetic mulch, e.g. polyester sheet, polyethene film, latex and starch resin spray mulches; c) soil mulch (no material put to the surface, but few centimeters of surface is disturbed mainly to prevent capillary evaporation in dry semi-arid areas).

Tillage

Since decades in cropping systems, Tillage has been used as method to control various weed species. Formerly, weed control was a side-product of seedbed preparation and weed control and management was not a prime objective of tillage practices. Manipulation of soil with tools and gears for untying and loosening the surface crust for bringing situations favorable for the seed germination and crop growth. It embraces both primary (moldboard plough, disc plough, etc.) and secondary tillage (disc harrow, cultivator etc.)

Cover Crop Residues

There are numerous possibilities through which Weed control and management can be efficiently obtained by means of cover crop residues. The use of cover crops helps to increase weed suppression without tillage. Cover crops can

compete with winter or summer weeds for water and light availability reducing the number of weeds. The cover crop residue also acts as a mulch to impede the germination and growth of weed seeds.

Mechanical Weed Control

Mechanical control consists of methods that kill or suppress weeds through physical disturbance. Such methods include digging, disking, pulling, plowing and mowing. Success of several mechanical control methods is defined by the life cycle of the marked target weed species (Cardina, *et al.*, 1996)

Mechanical weed management which starts with seedbed preparation depends on primary and secondary tillage tools for example the row cultivator and the rotary hoe. Partial reduced-till systems have been gradually developed for many vegetable crops. Mechanical control has sundry restrictions that must be considered while designing and developing weed-management systems. As relatively dry weather greatly effects mechanical management, thus a rainy period may eradicate options of mechanical management and may lead to potent weed competition. One should not Rely entirely on mechanical practices to manage weeds on large acreages as the results are not very promising (O'Donovan, *et al.,* 1985).

Hand pulling and digging is highly effective on biennial and annual weed species like musk thistle, kochia and diffuse knapweed. Annual weeds with upright and erect growth are controlled by hand digging effectively, while straight, prostrate, rosette and straight weeds get often torn off at the base or soil surface on drawing up by hands and may regenerate from tap roots left as such inside the soil.

Shallow tillage with a disk or sweep is effective for controlling annual species such as cheatgrass or kochia, but can essentially be counterproductive if trying to control perennial weeds such as field bindweed, Canada thistle, leafy spurge or Russian knapweed. Generally shallow and frequent pre-sowing tillage followed by irrigation is highly useful for controlling annual weeds (Das and Yaduraju, 2001).

Moldboard plowing (complete turnover of the top 10-12 inches of soil) disrupts underground root systems and buries seed from the surface to a depth too deep to germinate (Mauchline, *et al.,* 2005). This type of tillage is seldom feasible to practice on a regular basis. Moldboard plowing is usually the first step in mechanically managing weeds. It is particularly useful in controlling emerged annual weeds.

Mowing is a suppression measure that can prevent or decrease seed head construction. Mowed weeds will re-grow and put seed from a reduced height so a combined control method is necessary to be effective.

Biological Weed Control

Biological control is defined as "the control of an organism (weeds, insects or pathogens in agriculture) employing another living organism to a population lower than what naturally occurs in the absence of introduced/employed organism" (Gupta, 1998). They have just prey-predator relationship. The biological agents normally employed for the purpose could be parasites, predators (insects, mites), pathogens (fungi, bacteria, and viruses), deleterious *Rhizobacteria* (DRB), herbivorous fish, other animals (ducks and geese, snails) and botanical agents (competitive plants, crops or weeds) as applicable under a situation.

The goal of biological control is not eradication, but makes use of living agents to suppress vigor and spread of weeds (Lemerle, *et al.,* 1996). Such agents can be bacteria, fungi, insects, or grazing animals such as cattle, sheep, goats, or

horses. Grazing produces results similar to mowing, and bacteria and fungi are rarely available for noxious weed management. Biological control is most usually thought of as 'insect biocontrol' (Banks, *et al.*, 1976).

Insects

Opuntia Sp (Prickly Pear)

The cochineal insect *Dactylopius ceylonicus* Green (= *indicus* Green) was introduced for controlling *Opuntia vulgaris* Miller (*monacantha* Willdenow) Haworth in southern India around 1863 (Goeden, 1978) and this could be first successful biological control involving insects.

Parthenium Hysterophorus (Parthenium)

Among a dozen of bio-control agents (insects and pathogens) introduced in Australia and India, *Zygogramma bicolorata* Pallister and *Epiblema strenuana* have been found most effective in controlling parthenium.

Lantana *camara* (Lantana)

Lantana camara got introduced to Hawaiian Islands around 1860. It invaded large areas of rangelands there. Among several insects introduced in 1902 and later, *Crocidosema lantana* Busck (Tortricid moth), *Agromyza lantanae* (Seed fly) and *Thecla echion* and *Thecla bazochi* (Lycaenid butterfly) were very effective in controlling *Lantana*. Insects have effectively controlled *Lantana* in India, Australia and Fiji too.

Eichhornia *crassipes* (Water Hyacinth)

- ***Neochetina eichhorniae* Warner:** The larvae of *Neochetina* tunnel through the petioles and stems and thus open the way for soft-rotting bacteria. They are highly effective if *Eichhornia* is pre-treated with a growth retardant.
- ***Neochetina bruchii*:** *Neochetina bruchii* is another insect found effective in Australia.

Alternanthera *philoxeroides* Griseb (Alligatorweed)

Alligatorweed, a highly prolific aquatic weed has been controlled by Agasides hygrophylla and Agasides connexa Boheman (Flea beetle) in southern USA (Florida). The feeding efficiency of the insects increases if the weed is pre-treated with 2,4-D or diquat, which softens the foliage for insect attack.

Salvinia molesta

Successful biological control of *Salvinia molesta* was reported in 1974 by the grasshopper (*Paulinia acuminata*) in Lake Kariba, Zambia (Bennett and Woodford, 1980). The success of controlling *Salvinia* has also been reported from Papua New Guinea (Akobundu, 1987). *Salvinia* control through *Cyrtobagous salviniae* in Australia has added another dimension in biological control of weeds since 1980.

***Cyperus rotundus* (Purple Nutsedge)**

Bactra verutana Zeller (Moth borer) controlled *Cyperus rotundus* in India, Pakistan and USA.

Hypericum *perforatum* L. (St. John's Wort)

St. John's wort is a rangeland weed and also found here and there on the roadside. *Chrysolina hyperici* (Leaf-eating beetle) in Australia and New Zealand and *Chrysolina quadrigemina* Suffrian in western USA have been found effective in controlling St. John's wort.

Cattles, Goats, Sheep and Donkeys

Grazing by cattle, goats, sheep, donkeys etc. in pastures and fallow lands is a kind of natural control of unwanted floras and vegetation. *Senecio jacobaea* L. (Tansy ragwort) and *Rubus fruticosus* L. (Blackberry) have been effectively controlled by sheep in the pastures of Australia (Schmidl, 1977).

Mites

Among the mites, *Tetranychus desertorum* Banks against *Opuntia stricta* Haw. (Prickly pear) and *Aceria chondrillae* Can. (Gall mite) against the weeds *Chondrilla juncea* L. have been found effective in Australia. Another mite, *Orthogalummna terebrantis* Wal. has been tried against *Eichhornia crassipes* (Water hyacinth).

Manatees

Manatees (*Trichechus sp*) are a large plant eating sea mammal and had been introduced in Florida waterways for weed control. It, however, cannot breed in fresh water and therefore, is restricted to saline/salty water.

Ducks and Geese

Ducks and geese have also been experimented for aquatic weed control in rice culture, cotton (Crafts, 1975), strawberries, mint and some other crops. The geese prefer seedlings of grass weeds. However, ducks/geese and fish and/or snail cannot be introduced simultaneously in the same rice culture, since ducks and geese may be predators of fish and snail.

Snails

A large fresh water snail, *Marisa cornuarieties* L. and some other snails in Florida and Puerto Rico have been evaluated for the control of several submerged aquatic weeds and algae. *Marisa cornuarieties*, however, proved most effective. *Marisa* feeds on the roots of *Eichhornia crassipes* (Water hyacinth) and *Pistia stratiotes* (Water lettuce) and the leaves of *Salvinia molesta*. It, however, attacks rice seedlings and *Trapa natans* (Water chestnut) and, therefore, should not be introduced in rice fields where water chestnut, a plant of economic value grows.

Fish

Several herbivorous fish such as *Cyprinus carpio* L. (Common carp), *Ctenopharyngodon idella* Val (White amur/Chinese grass carp), *Tilapia mossambica* (Sunfish), have been introduced and found useful for aquatic weed control in ponds, waterways and in lowland rice ecosystem. Chinese grass carp is a voracious eater/feeder and eats more than its body weight daily. It may grow at a rate of 5 kg/year and attains 50 kg or more body weight at its full size (Gupta, 1973). It proved highly effective for aquatic weed control in many countries including India.

Deleterious Rhizobacteria (Drb)

The *Rhizobacteria* usually colonize around the rhizosphere of certain weeds and decrease their root growth and proliferation. As a result, the weeds remain stunted and cannot exert enough competition to crop plants. The *Rhizobacteria* possessing this attribute is called "deleterious *Rhizobacteria* (DRB)." Research on deleterious *Rhizobacteria* is still in its infancy, but some experiments showed their potential towards growth inhibition of weeds.

Advantages of Biological Control

Biological control is environmentally benign/eco-friendly since it does not lead to environmental contamination. It is self-perpetuating/self-sustaining except bioherbicides. Classical biological control does not need to introduce insects/bio-agents repeatedly in every year or every crop season and, therefore, relatively permanent and longer lasting. It is economical in the long run, although initially monetary investment is high. It preserves bio-diversity since weed control by biological means/agents is not achieved to the level of 100%. It is effective in areas inaccessible to man. That weed wherever found even in dense forest, high mountains, is likely to be controlled particularly by insect bio-agents.

Disadvantages of Biological Control

It requires/incurs higher initial cost. The biological control warrants the use of other pesticides such as insecticide, fungicide in the crop, which may kill the bio-agents or hamper its activity. Screening and identification of bio-agents if not proper, they may damage the economic crops or they may control weed plants of economic interest in other places. For example, *Zygogramma bicolorata* Pallister (Mexican beetle) and *Epiblema strenuana* Walker (gall-forming insect) meant for parthenium (*Parthenium hysterophorus* L.) control also feed on sunflower and niger, respectively. Biological control has limited use/adoption in a crop field, which usually witnesses a composite culture of weeds. It is in most cases weed-specific and the weed is managed at a lower density. Controlling a single weed unless it is rampant having widely distributed in large areas and highly damaging to crop or ecosystem, is of less use/benefit.

Approaches to Biological Control of Weeds

Classical/Inoculative Approach

Classical/inoculative approach involves the release of bio-agents (insects, pathogens) just for once in the belief that it will readily adapt to the prevailing climate and multiply enough to keep pace with the multiplication rate of weed in question. Therefore, repeated release of bio-agent unless failed, is not advocated.

No augmentation and large-scale mass production of the bio-agent are practiced. In this approach, a small amount of inoculum (pathogen) or a small number of insects, say, one insect per 20-40 weeds or 1 insect per 3-5 m2 area based on the assessment of weed problem and prevailing situation, is initially released in the standing population of weeds and allow it to multiply and feed on the weeds.

Augmentative Bio-Herbicide Approach

This type of approach pursues *in vitro* augmentation of the pathogen inoculums and its culturing in artificial medium in the laboratory on the belief that target weeds may fall susceptible to it when applied in a large concentration (considering the number of active bio-agent molecules) over its existing population.

These inoculums are bio-herbicide. Bio-herbicides are native pathogens mostly fungi and hence called mycoherbicide. Several inoculums such as fungi, bacteria, parasitic nematodes, viruses having tested control ability over a weed species may be applied like herbicides.

Bioherbicides are sprayed in every season on the target weed in crop field. The bio-agent generally remains active only on concurrent weed population. Then they wither away without any cyclic perpetuation unlike what happens in classical bio-control. However, in some cases, the pathogen may remain active for 3-4 years e.g. soil-borne pathogen *Phytophthora citrophthora* p.v. *palmivora* for the control of *Morrenia odorata* (Strangler vine) in citrus.

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